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NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DETERMINATION OF THE SUN'S DISTANCE, FROM OBSERVATIONS OF *EROS*.

The tendency of the times toward thorough organization and co-operation in large enterprises is well illustrated in modern astronomy. Thirty years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian-circle observations would combine to form the excellent Astronomische Gesellschaft star-catalogue; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris, some ten years ago.

About fifty of the principal observatories of the world are now co-operating in a great programme of observation for improving our knowledge of the distance between the Earth and Sun. Fully half the resources of the Lick Observatory have been devoted to this work for two months past, and the observations will continue one or two months longer.

The determination of the value of this astronomical unit of distance is one of the most famous problems in the science, and a great variety of methods has been used. Perhaps the best determination is that made by Sir DAVID GILL of the Cape of Good Hope, from heliometer observations of the nearer asteroids. The four hundred small planets (asteroids) discovered up to 1898 all move in orbits situated entirely outside the orbit of *Mars*. The observations of *Victoria*, *Iris*, and *Sappho*, which approach nearer to the Earth than any of the other members of the asteroid group, led to the result that the average distance from the Earth to the Sun is about 92,900,000 miles. The unavoidable errors to which all such observations are subject leave an uncertainty of some 150,000 miles in this value: it may be too large or too small by this amount.

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The accuracy of results obtained in this manner depends upon the distance of the observed body from the Earth, and upon its definiteness as a point of observation. *Mars* possesses the advantage of being nearer the Earth than the asteroids, but this advantage is greatly outweighed by the fact that an asteroid-point can be observed much more accurately than a large planet-disk. GILL's splendid work left much to be desired, but there was no prospect that his value of the unit could be improved with instruments now available.

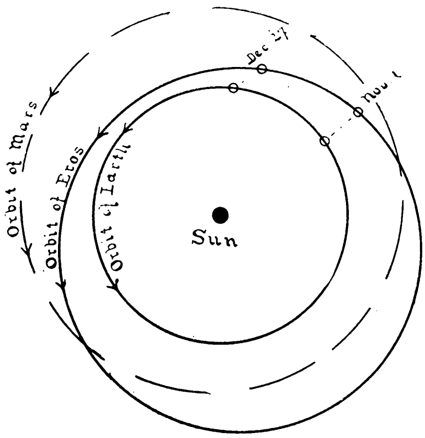

Fig. 1

An asteroid discovered by Dr. WITT in Berlin, in 1898, to which he gave the name *Eros*, is very remarkable in that its orbit lies partly within and partly without the orbit of *Mars*. It approaches the Earth more closely than any other member of our system, except the Moon. The forms and relative positions of the orbits of the Earth, *Eros*, and *Mars* are shown approximately by the accompanying diagram (Fig. 1). The orbits of *Mars* and *Eros* appear to intersect; but this is merely apparent, from the projection of the two on the plane of the paper. The plane of the orbit of *Eros* makes an angle of about eleven degrees with the plane of the orbit of *Mars* (and the Earth), and the two orbits are situated like two adjacent links of a chain without approaching each other very closely.

As soon as the orbit of this wonderfully-located asteroid was computed and published, astronomers realized its possibilities for improving our knowledge of the Sun's distance. As stated above, an asteroid's value for this purpose depends upon its closeness to the Earth. The distance of *Eros* at this opposition will have a minimum value of 27,000,000 miles. Unfortunately, the more favorable opposition of 1896, when the distance diminished to 15,000,000 miles, was not available, as the planet remained undiscovered; and an equally good opposition will not occur again for a quarter of a century.

In outline, this method of measuring the Sun's distance is exceedingly simple; but in detail it is exceedingly complex and technical. The nature of the problem may be explained from Fig. 2.

If the Earth is at E and the asteroid at A, an observer on the Earth's surface at P will see the asteroid projected on the sky at P′, whereas an observer at L will see it at L′. If the distance PL is known, as it is, and the angle PAL is obtained from the observations, the data for solving the triangle PLA are at hand, and the distance EA may be obtained by simple computation. As a second step in the solution, the orbit of *Eros* will be determined very accurately, basing the determination upon NEWTON'S law of gravitation. It will then be a simple matter to compute the ratio of the Earth's distances from the Sun (ES) and the asteroid (EA). The distance EA having already been determined in miles, the desired distance ES will follow.

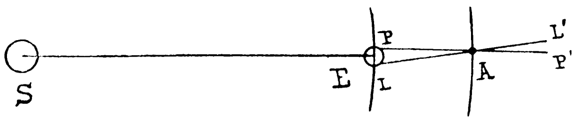

Fig 2

If two observatories on opposite sides of the Earth secure observations simultaneously, say at P (Pulkowa, in Russia) and at L (Mt. Hamilton), the desired data are theoretically complete; but practically they are insufficient. There are unavoidable errors in the measurement of the very small angle PAL, and in the assumed positions of the two observatories, which will be materially reduced by having observations made at a large number of stations. The direct distance between the Pulkowa and Lick Observatories is about 5,000 miles. This is a base-line from which to measure a distance of 27,000,000 miles, and thence the three-and-one-half-fold greater distance to the Sun. The form and the dimensions of the Earth thus enter directly into the problem. An error of a quarter of a mile in the assumed length of the base-line leads to a large error in the final result.

Instead of simultaneous observations made in the morning in Russia and in the evening in America, the angle PAL can be determined by evening and morning measures secured at one station.

The July conference of astronomers at the Paris Exposition afforded an opportunity for a hurried formation of co-operative plans to secure the observations needed. It may be said that every one of the contributing observatories is devoting to this problem all of its resources which in any way promise to improve the results. The measures are most advantageously made in November and December; and perhaps a hundred observers are giving their time to this work. The reductions will require one or two years' labor, and the value of the Sun's distance, resulting from a combination of all the work of all the observatories will probably not be available for two or three years.

The Lick Observatory is contributing as follows:—

Astronomer R. H. TUCKER, assisted by Mr. CRAWFORD, is securing two meridian-circle observations of each of 700 stars, to determine their positions with the utmost accuracy. These positions, furnished by perhaps a dozen or more observers, will form the triangulation system, or groundwork, upon which the whole structure of the determination will be based.

Astronomer W. J. HUSSEY and Assistant Astronomer R. G. AITKEN, with the assistance of Mr. WRIGHT and Dr. REESE, are using the great telescope five or six nights per week, weather permitting, to measure the evening and morning positions of *Eros* with reference to the fixed stars in the asteroid's vicinity. The positions of these reference-stars will be secured by means of photographs of the regions taken with eight or ten telescopes, mostly in Europe.

Assistant Astronomer C. D. PERRINE, assisted by Mr. PALMER, is employing the Crossley reflector every clear night to obtain photographs of *Eros* and its surrounding stars, to furnish the planet's accurate position in the evening, in the morning, and on the meridian. The measurement of these plates will be a heavy task. Fortunately, Professor REES, Director of the Columbia University Observatory, has volunteered to measure them. Columbia University is the only institution in this country which has had experience in measuring such plates, though many foreign observatories have long been doing similar work.

The planet *Eros* is now of about the 9.3 magnitude. It is easily visible in a three-inch telescope. W. W. CAMPBELL.

LICK OBSERVATORY, November 24, 1900.